

## THE CLAIMS

### What is claimed is:

1. A system for abatement of effluent including one or more contaminant a main abatement tool and a polishing scrubber for removal of any remaining contaminants in the effluent discharged from the main abatement tool, wherein the polishing scrubber includes one or more compatible features selected from the group consisting of:

(A) a water scrubbing system wherein the effluent includes ammonia and one or more fluorine-containing species, comprising a sump for collection of aqueous scrubbing medium, and the water scrubber being constructed and arranged to recirculate the aqueous scrubbing medium and provide a residence time of the aqueous scrubbing medium that is sufficient to solubilize sufficient ammonia to form ammonium hydroxide in sufficient amount to substantially remove fluorine-containing species from the effluent without forming  $\text{OF}_2$ ;

(B) a recirculating scrubber constructed and arranged to recirculate an ancillary scrubbing medium in a closed loop for contacting of the scrubbed effluent, to remove residual gases unabated by the main abatement tool and to destroy unwanted by-product fluorine-containing species in the scrubbed effluent;

(C) a scrubber comprising a dry scrubber medium effective for removing  $\text{OF}_2$  in contact therewith, wherein the dry polishing scrubber is constructed and arranged to contact

said scrubbed effluent with the dry scrubber medium, to substantially remove  $\text{OF}_2$  from the scrubbed effluent;

(D) a catalytic decomposition system including a catalyst medium effective to catalytically enhance decomposition of  $\text{OF}_2$  in contact therewith, wherein the catalytic decomposition system is constructed and arranged to contact the scrubbed effluent with the catalyst medium, to catalytically decompose and substantially remove  $\text{OF}_2$  from the scrubbed effluent; and

(E) an ultraviolet radiation decomposition system including an ultraviolet radiation source arranged to emit ultraviolet radiation effective for decomposition of  $\text{OF}_2$  in exposure thereto, wherein the ultraviolet radiation decomposition system is constructed and arranged to expose the scrubbed effluent to said ultraviolet radiation from the ultraviolet radiation source, to decompose and substantially remove  $\text{OF}_2$  from the scrubbed effluent.

2. The system of claim 1, wherein the main abatement tool comprises a wet scrubbing system, a dry scrubbing system, a plasma dissociation system, a thermal degradation system, a flame oxidation/destruction system, or a photo decay system.

3. The system of claim 1, comprising the polishing scrubber of (A).

4. The system of claim 3, arranged in effluent-receiving relationship with a silicon nitride semiconductor process tool including a plasma reactor constructed and arranged

for combination of silane, ammonia and an oxidizing agent during silicon nitride deposition, and for subsequent chamber clean of the plasma reactor generating molecular fluorine and other fluorine-containing compounds as effluent components.

5. The system of claim 3, wherein residence time of the aqueous scrubbing medium in the sump is in a range of from about 0.25 to about 10 minutes during said silicon nitride deposition.

6. The system of claim 3, wherein residence time of the aqueous scrubbing medium in the sump is sufficient to achieve a solubilization of ammonium hydroxide in a concentration range of from about 0.001 grams per liter to about 30 grams per liter.

7. The system of claim 1, comprising (B).

8. The system of claim 7, wherein the recirculating post scrubber comprises a vessel containing a packed bed of packing material facilitating gas/liquid contacting.

9. The system of claim 8, wherein the packed bed has a void volume in the range of from about 30 % to about 70 %, based on the total volume of the bed.

10. The system of claim 8, wherein the packed bed has an average surface to volume ratio of the packing elements in a range of from about 10,000 cm<sup>-1</sup> to about 100,000 cm<sup>-1</sup>.

11. The system of claim 8, wherein the bed is confined in the vessel to a fixed spatial location.

12. The system of claim 8, wherein the ancillary scrubbing medium comprises a reducing agent.

13. The system of claim 12, wherein the reducing agent comprises a reducing agent selected from the group consisting of sodium thiosulfate, ammonium thiosulfate, ammonium hydroxide, ammonium fluoride, and combinations of two or more thereof.

14. The system of claim 8, wherein the ancillary scrubbing medium comprises a liquid phase material capable of removing  $\text{OF}_2$  from the scrubbed effluent.

15. The system of claim 8, wherein the ancillary scrubbing medium comprises an organic fluid capable of removing  $\text{OF}_2$  from the scrubbed effluent.

16. The system of claim 8, wherein the ancillary scrubbing medium comprises a dissolved inorganic salt capable of removing  $\text{OF}_2$  from the scrubbed effluent.

17. The system of claim 1, comprising (C).

18. The system of claim 17, wherein the dry scrubber medium comprises carbon.

19. The system of claim 18, wherein the carbon comprises activated carbon.

20. The system of claim 18, wherein the carbon is in a bead form.
21. The system of claim 18, wherein the carbon is in a honeycomb form.
22. The system of claim 17, further comprising a heater for heating the dry scrubber medium to elevated temperature.
23. The system of claim 17, wherein the dry scrubber medium comprises a calcium hydroxide resin.
24. The system of claim 23, further comprising a heater for heating the dry scrubber medium to elevated temperature.
25. The system of claim 18, wherein the dry scrubber medium comprises a material reactive with  $\text{OF}_2$  to abate same, selected from the group consisting of calcium hydroxide, copper hydroxide, sodium hydroxide, magnesium hydroxide, lithium hydroxide, potassium hydroxide, barium hydroxide and ammonium hydroxide.
26. The system of claim 17, wherein the dry scrubber medium comprises a bed of heated elemental metal reactive with fluorine-containing species in the effluent to abate same.

27. The system of claim 26, wherein the heated elemental metal comprises a metal selected from the group consisting of copper, aluminum and iron.

28. The system of claim 26, wherein the heated elemental metal comprises a metal disposed on a support in the post scrubber.

29. The system of claim 26, wherein the heated elemental metal comprises a metal in divided form, constituting a packed bed in the post scrubber.

30. The system of claim 26, further comprising means for maintaining the heated elemental metal at a sufficient temperature for the elemental metal to react with fluorine in the effluent to form a corresponding metal fluoride.

31. The system of claim 1, comprising (D).

32. The system of claim 31, wherein the catalyst medium comprises a transition metal.

33. The system of claim 32, wherein the transition metal is supported on a support element.

34. The system of claim 33, wherein the support element comprises a honeycomb structure.

35. The system of claim 32, wherein the transition metal is in an elemental metal form.

36. The system of claim 31, further comprising means for heating the catalyst medium to an elevated temperature sufficient to effect catalytic decomposition of  $\text{OF}_2$ .

37. The system of claim 1, comprising (E).

38. The system of claim 37, wherein said ultraviolet radiation from said ultraviolet radiation source comprises UV radiation having a wavelength in the vicinity of 365 nanometers.

39. The system of claim 37, wherein the ultraviolet radiation decomposition system is constructed and arranged to operate at temperature in a range of from about  $15^\circ\text{C}$  to about  $45^\circ\text{C}$ .

40. The system of claim 37, wherein the ultraviolet radiation decomposition system is constructed and arranged to successively expose the effluent to differing wavelengths of ultraviolet radiation.

41. A method for abatement of effluent including one or more contaminants including fluorine-containing species, ammonia, or silane, the method comprising:  
treating effluent in a main abatement tool;  
discharging treated effluent from the main abatement tool to a polishing scrubber; and  
treating discharged effluent with one or more additional compatible steps selected from the group consisting of the following:

(A) scrubbing a previously treated effluent comprising ammonia and one or more fluorine-containing species with an aqueous scrubbing medium, collecting the aqueous scrubbing medium in a collection volume thereof, and recirculating the aqueous scrubbing medium from the collection volume to the scrubbing step, with a residence time of the aqueous scrubbing medium in the collection volume being maintained to solubilize sufficient ammonia to form ammonium hydroxide in sufficient amount to substantially remove the fluorine-containing species from the effluent without formation of  $\text{OF}_2$ ;

(B) recirculating an ancillary scrubbing medium in closed loop contacting of the previously treated effluent, to remove residual gases unabated by previous treatment and to destroy unwanted by-product fluorine-containing species in the scrubbed effluent;

(C) contacting the previously treated effluent with a dry scrubber medium effective for removing  $\text{OF}_2$  from said treated effluent;

(D) contacting the previously treated effluent with a catalyst medium effective to catalytically enhance decomposition of  $\text{OF}_2$  in contact therewith, to catalytically decompose and substantially remove  $\text{OF}_2$  from the treated effluent; and



(E) exposing the previously treated effluent to ultraviolet radiation effective for decomposition of  $\text{OF}_2$  in exposure thereto, to decompose and substantially remove  $\text{OF}_2$  from the treated effluent.

42. The method of claim 41, comprising (A).

43. The method of claim 42, wherein the effluent derives from a silicon nitride semiconductor process tool including a plasma reactor constructed and arranged for combination of silane, ammonia and an oxidizing agent during silicon nitride deposition, and for subsequent chamber clean of the plasma reactor generating molecular fluorine and other fluorine-containing compounds as effluent components of the effluent.

44. The method of claim 42, wherein residence time of the aqueous scrubbing medium in the aqueous scrubbing medium collection volume is in a range of from about 0.25 to about 10 minutes during said silicon nitride deposition.

45. The method of claim 42, wherein residence time of the aqueous scrubbing medium in the aqueous scrubbing medium collection volume is sufficient to achieve a solubilization of ammonium hydroxide in a concentration range of from about 0.001 grams per liter to about 30 grams per liter.

46. The method of claim 41, comprising (B).

47. The method of claim 46, wherein the ancillary scrubbing medium is recirculated through a packed bed of packing material facilitating gas/liquid contacting in said closed loop gas/liquid contacting.

48. The method of claim 47, wherein the packed bed has a void volume in the range of from about 30 % to about 70%, based on the total volume of the bed.

49. The method of claim 47, wherein the packed bed has an average surface to volume ratio of the packing elements in a range of from about 10,000 cm<sup>-1</sup> to about 100,000 cm<sup>-1</sup>.

50. The method of claim 47, wherein the bed comprises a fixed bed.

51. The method of claim 47, wherein the ancillary scrubbing medium comprises a reducing agent.

52. The method of claim 51, wherein the reducing agent comprises a reducing agent selected from the group consisting of sodium thiosulfate, ammonium thiosulfate, ammonium hydroxide, ammonium fluoride, and combinations of two or more thereof.

53. The method of claim 47, wherein the ancillary scrubbing medium comprises a liquid phase material capable of removing OF<sub>2</sub> from the scrubbed effluent.

54. The method of claim 47, wherein the ancillary scrubbing medium comprises an organic fluid capable of removing OF<sub>2</sub> from the scrubbed effluent.

55. The method of claim 47, wherein the ancillary scrubbing medium comprises a dissolved inorganic salt capable of removing OF<sub>2</sub> from the scrubbed effluent.

56. The method of claim 41, comprising (C).

57. The method of claim 56, wherein the dry scrubber medium comprises carbon.

58. The method of claim 57, wherein the carbon comprises activated carbon.

59. The method of claim 57, wherein the carbon is in a bead form.

60. The method of claim 57, wherein the carbon is in a honeycomb form.

61. The method of claim 56, further comprising heating the dry scrubber medium to elevated temperature.

62. The method of claim 56, wherein the dry scrubber medium comprises calcium hydroxide.

63. The method of claim 62, further comprising heating the dry scrubber medium to elevated temperature.

64. The method of claim 56, wherein the dry scrubber medium comprises a material reactive with  $\text{OF}_2$  to abate same, selected from the group consisting of calcium hydroxide, copper hydroxide, sodium hydroxide, magnesium hydroxide, lithium hydroxide, potassium hydroxide, barium hydroxide and ammonium hydroxide.

65. The method of claim 56, wherein the dry scrubber medium comprises heated elemental metal reactive with fluorine-containing species in the effluent to abate same.

66. The method of claim 65, wherein the heated elemental metal comprises a metal selected from the group consisting of copper, aluminum and iron.

67. The method of claim 65, wherein the heated elemental metal comprises a metal disposed on a support.

68. The method of claim 65, wherein the heated elemental metal comprises a metal in divided form.

69. The method of claim 65, further comprising maintaining the heated elemental metal at a sufficient temperature for the elemental metal to react with fluorine in the effluent to form a corresponding metal fluoride.

70. The method of claim 41, comprising (D).

71. The method of claim 70, wherein the catalyst medium comprises a transition metal.
72. The method of claim 71, wherein the transition metal is supported on a support element.
73. The method of claim 72, wherein the support element comprises a honeycomb structure.
74. The method of claim 71, wherein the transition metal is in an elemental metal form.
75. The method of claim 70, further comprising heating the catalyst medium to an elevated temperature sufficient to effect catalytic decomposition of  $\text{OF}_2$ .
76. The method of claim 41, comprising (E).
77. The method of claim 76, wherein said ultraviolet radiation comprises UV radiation having a wavelength in the vicinity of 365 nanometers.
78. The method of claim 76, wherein the scrubbed effluent is exposed to ultraviolet radiation at temperature in a range of from about 15°C to about 45°C.
79. The method of claim 76, wherein the scrubbed effluent is successively exposed to differing wavelengths of ultraviolet radiation.